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Investigation of various physicochemical and environmental parameter influence on pesticide sorption to ditch bed substratum by means of experimental design

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Abstract

Diffuse pollution by pesticide applied in rural catchments may contribute to alter water quality. Besides actions relative to the way the substances are introduced into the environment, it is also possible to limit the contamination by interfering on their transfer pathways from fields to the main river network. Especially, interface areas such as buffer strips or small ditches may play a major part in pesticide diffuse pollution decrease. In ditches a great variety of materials may act as sorbents for organic contaminants: grass, leaves, wood debris or sediments. In this study, laboratory experiments were designed to determine sorption characteristics for three herbicides with different physicochemical properties on sediment and leaves in decay commonly found in agricultural ditches. Sorption capacities were assessed for the herbicides isoproturon, diuron and diflufenican.

Experimental design was carried out to investigate the effects of five parameters on herbicide sorption on sediment and dead leaves. These parameters have been chosen according to parallel field experiment needs. Thus, the influence of initial sorbent moisture, herbicide form, i.e. active substance or commercial formulation, water quality (tap or natural ditch water), bromide ions (used as conservative tracers) and solid/liquid ratio have been tested. Within the parameters investigated, pesticide formulation and solid/liquid ratio were the most important parameters affecting pesticide sorption on both ditch materials.

Keywords: Pesticides; Adsorption; Ditch materials; Leaves; Sediment; Experimental design

1. Introduction

Agricultural non-point pollution originates from land areas which may intermittently contribute to the transport of pesticides to surface water by runoff, drainage, leaching, aerial deposition or drift. Many methods and levels of actions can be developed to reduce this transfer. For example, new or improved agricultural practices can be set up, such as choosing the best application period, controlling toxic substance impacts, or using non-chemical practices (Baker et al., 1995). However once pesticides are applied, diffuse losses cannot be totally prevented, due to the uncontrollable soil and climate characteristics involved in diffuse pollution. Pesticides leaving a plot in runoff may pass through

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different landscape components before reaching rivers, including other fields, ditches, brooks and vegetative or wooded buffer zones. Only few in situ experiments have been carried out concerning the role played by farm ditches in reducing water contamination by pesticides (Williams et al., 1999; Moore et al., 2001; Cooper et al., 2004). Despite the heterogeneity of the situations encountered, field experimentations in ephemeral ditches with rapid water flows revealed that pesticide retention was linked to the substratum nature, the hydrodynamic conditions, and also to the contaminant physicochemical properties. Therefore it is essential to better characterise pesticide sorption ability to typical sorbents found in such buffer zones by means of well controlled trials.

Laboratory studies were then conducted to determine the sorption behaviour of three herbicides with different physicochemical properties (isoproturon: 3-(4-isopropylphenyl)-1,1-dimethylurea, diuron: 3-(3,4-dichlorophenyl)-1, 1-dimethyurea, and diflufenican: 2′4′-difluoro-2-(α,α, α-trifluoro-*m*-tolyloxy)nicotinanilide) on bed sediment and dead leaves which are common substratum in French ditches (Margoum et al., 2001). In the present paper, herbicide sorption was studied as a function of different influencing parameters including the form of the sorbates, the sorbents and the water characteristics. The influence of some of these factors has already been studied with other sorbents or pesticides (Lickfeldt and Branham, 1995; Beck and Jones, 1996; Gaillardon, 1996; Walker and Jurado-Exposito, 1998; Chaplain et al., 2001). However, conclusions were in contradiction. On the one hand, Lickfeldt and Branham (1995) investigated the adsorption capacity of several non-ionic compounds on leaves and thatch, and concluded that these chemicals were more adsorbed when formulated or with the presence of dissolved organic matter. On the other hand, Beck and Jones (1996) observed non significant influence of dissolved organic matter on atrazine and isoproturon sorption on soils. Gaillardon (1996) showed that soil moisture enhanced sorption speed and increased final sorption for diuron on soils.

The aim of the present study was to complement preliminary field experimental results concerning the role played by ephemeral ditch materials on pesticide retention (Margoum et al., 2003), by studying the influence of five different but not exhaustive parameters on sorption. Then, we qualitatively estimated to which extent (a) initial sorbent moisture, since the hydratation status may modify its hydrophobic properties; (b) formulated herbicide substances used in field experiments as presented before; (c) water quality, and especially organic matter content (Caron et al., 1985; Chiou et al., 1986; Flores-Cespedes et al., 2002); (d) bromide ions used as conservative tracers in experiments concerning pesticide transfer studies (Allaire-Leung et al., 1999; Schoen et al., 1999), and (e) solid/liquid ratio (Boesten and Van Der Pas, 1988; Walker and Jurado-Exposito, 1998) could play a significant role in herbicide sorption on typical ditch sorbents. A fractional factorial experimental design and columns of contrast coefficients calculation were used for rapid assessment of the effects of the five studied parameters.

2. Experimental

2.1. Chemicals and reagents

Three chemicals were used in this research. Isoproturon (99%), diuron (97.5%) and diflufenican (99.5%) were of analytical grade supplied by Cluzeau Info Labo (Sainte Foy la Grande, France) (Table 1). These herbicides are commonly used in agricultural catchments for weed control.

The commercial formulations were Zodiac TX that contained isoproturon (500 g l^{-1}) and diflufenican (100 g l^{-1}), and Séduron (diuron at 500 g l^{-1}) both from Bayer Crop Science.

All organic solvents used for standard solution, extraction or chromatographic analysis were pesticide or gradient HPLC grade (SDS, Peypin, France).

2.2. Sorbents

Sorbents were chosen in accordance with agricultural ditches previously studied (Margoum et al., 2003), i.e. poor organic matter sediments and leaves in decay to have a large range of sorbent properties. Ditch bed sediment was collected in Roujan, southern France (Louchart et al., 2001). The sediment (clay: 305 g kg^{-1}; silt: 483 g kg^{-1}; sand: 212 g kg^{-1}) was air-dried and passed through a 2-mm sieve before any experimental use.

Table 1
Properties of the studied herbicides (Tomlin, 2000; INRA, 2005)

Characteristics	Isoproturon (IPU)	Diuron (DIU)	Diflufenican (DFF)
Solubility in water (mg l^{-1})	65 (22 °C)	36.4 (25 °C)	0.05 (25 °C)
K_{oc} (l kg^{-1})	36–241	480	1622–2369
log K_{ow}	2.5	2.85	4.9
Half life (day)	6–28	90–180	105–210